Swami Ramanand Teerth Marathwada University, Nanded

Faculty of Science and Technology in the subject of Physics

"Synthesis, Characterization and Photoelectrochemical Application of Chemically Deposited $CuInTe_2$ Thin Films"

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Abstract of proposed work plan/problem

Research work based on $CuInTe_2$ thin films will be deposited onto glass substrates using a chemical deposition method. Optical, Electrical, Structural, Morphological, Compositional, and Photoelectrochemical properties of the as-deposited $CuInTe_2$ thin films will be studied using UV-Vis Spectroscopy, DC electrical conductivity measurement, X-ray diffraction, Scanning Electron Microscopy, EDAX, and PEC characterization techniques.

1. Introduction

Thin film chemical deposition techniques are a new area of research due to their benefits, widespread range of applications and inexpensiveness. Thin films have very low thickness and can be synthesized by the deposition of materials on a substrate with the required temperature with a suitable method. Films are deposited by condensation of one-by-one of atomic, molecular or ionic species of matter. Compared to bulk solids, thin films have a larger surface-to-volume ratio, hence the surface characteristics decide the characteristics and properties of the thin film. The properties of thin films depend not only on the thickness of the film but also, on the nature of the substrate upon which the films are grown and the deposition parameters used in the fabrication process. The capability of controlling the properties of thin films helps in the development of new products and minimizes wastage as in predictable manufacturing techniques. Owing to compactness, better performance, reliability and low production cost, thin film devices are preferred over their bulk counterparts. Prepared samples have led to the development of devices ranging from energy-efficient devices to energy harvesting and energy storage devices such as solar cells, sensors, memory, batteries, supercapacitors, etc. As a result, thin film deposition technology is a major area of scientific research.

Photovoltaic devices and solar cells are among the most important applications of thin films. Solar energy is one of the greatest in-demand, clean and alternative energy sources to accomplish the energy needs of the world. Thin film solar cells are comparatively cheap, thinner in size and more flexible than silicon wafer solar cells. TFSC (thin film solar cell) technology has huge potential to produce better solar cells and PV devices, hence research has been continued in this field. Varieties of materials have been found to be suitable for solar energy conversion through the photovoltaic method.

The I-III-VI_2 chalcogenide (chalcopyrite) ternary compounds are promising semiconductor materials that have been studied in recent times for photovoltaic applications. Chalcopyrite ternary compounds like CIGS, $CuSbS_2$, $CuInSe_2$ $CuInGaSe_2$, $CuInTe_2$, etc. have been studied due to their interesting properties and applications in optoelectronic devices like LEDs, Infrared detectors, IR generators, PV devices, etc. [1-8]. $CuInTe_2$ is one of the competent materials for solar cell applications [1-11]. It has a direct band gap, which falls in the optimum range for conversion of solar energy [2, 5]. The absorption coefficient is also high in the order of 10^5 cm^{-1}, which makes it possible to use only a few microns thick films to make devices [1, 4]. The material can be made of p-type as well as n-type conductivity [6]. Different methods like flash evaporation, electrochemical deposition, vacuum evaporation, chemical spray pyrolysis, PLD, etc. have been used to prepare $CuInTe_2$ thin films [2, 4].

In the present study, $CuInTe_2$ thin films will be deposited by chemical deposition technique. Chemical deposition method is used because it is a simple and cost-effective technique that can be used to deposit large-area films. Various properties of deposited thin films like optical, electrical, crystal structure, morphology, composition and PEC effect will be studied.

2. Review of literature and development in the subject:

The highest efficiency with Cu- In –Te base absorber was reported 5.1 % by using conventional MBE system [12].

Spray pyrolyzed thin films were found to have cubical structure. The crystallite size of films was found to increase up to 350°C and then decreased [13].

The deposited films showed a tetragonal structure. The crystallite size was seen to be dependent upon the deposition potential and chemical concentration of precursors. The films were

Te rich and the solar cells fabricated using $CuInTe_2$ as an absorber layer had 4.13% efficiency [3]. The synthesis of bulk $CuIn_5Te_8$ single crystals grown by direct crystallization of near-stoichiometric melt and discussed the possibility to achieve broadband photosensitivity under illumination of the barrier side of these crystals. The $CuIn_3Te_5$ ingot by the Bridgman method and studied by impedance spectroscopy at different temperatures [14, 15].

It was observed that stirring causes stoichiometric and crystalline films to be produced. It was seen that the pH and temperature increased the solubility of TeO_2 which increases the thickness of thin films up to a certain level. Smooth and uniform thin films were deposited having a direct band gap [16-20].

Band gap was found to increase with higher negative potential, annealing and altering composition. Annealing increased the grain size of thin films and decreased Te concentration. Deposited $CuInTe_2$ thin films by electrodeposition were loosely bound clusters of crystallites. Both amorphous and tetragonal chalcopyrite thin films were formed with p-type conductivity [21, 22].

The stoichiometry of prepared thin films was found to increase with the increase in substrate temperature while the band gap was seen to decrease. The photosensitivity of thin films was observed to be inversely proportional to film thickness [8, 23].

Polycrystalline, single-phase thin films of both n-type and p-type conductivity were deposited. The hall coefficient of n-type thin films was found to remain constant with an increase in substrate temperature. It was seen that chalcogen deficiency in grains at low substrate produced n-type conductivity [9].

The thickness was increased and the band gap was decreased with an increase in substrate temperature till 350°C and then decreased further [24].

3. Objectives of research/Proposed hypothesis:

The following are the objectives of the present research work:

i. To synthesize good quality $CuInTe_2$ thin films via chemical deposition technique by optimizing various deposition parameters.

ii. To characterize $CuInTe_2$ thin films for structural, morphological, compositional, optical, and electrical properties.

iii. To study the photovoltaic solar cell performance of $CuInTe_2$ thin films deposited on amorphous and FTO-coated conducting glass substrates.

iv. To study the effect of electrode thickness on the properties of $CuInTe_2$ thin films.

4. Methodology to be adopted

There are various techniques available for deposition of thin films. Chemical methods have advantages like simplicity, safety, low cost, and high production rate compared with physical deposition methods. Using the chemical methods helps with the deposition of thin films of a variety of elements, on diverse substrates, and at relatively lower temperatures. The chemical method will be used to synthesize $CuInTe_2$ thin films.

The work will be divided in the following manner:

a) Preparation of Good Quality $CuInTe_2$Thin Films:

It is proposed to grow $CuInTe_2$ thin films by chemical method. At the initial stages, efforts will be made in order to deposit good quality $CuInTe_2$ thin films on glass substrates. The various preparative parameters like concentration of precursor solution, deposition temperature and other parameters will be optimized to get good quality $CuInTe_2$ thin films. The as-deposited films will be characterized by various characterization techniques.

b) Structural Studies:

The as-deposited $CuInTe_2$ thin films will be characterized by X-ray diffraction (XRD) technique. The crystal structure, interplanar spacing, lattice planes, lattice parameters and crystallite size will be realized and correlated with the film properties.

c) Morphological and Compositional Studies:

The morphology of the prepared $CuInTe_2$ thin films will be studied by using Scanning Electron Microscopy (SEM). The compositional analysis of as-deposited $CuInTe_2$ thin films will be studied by using the Energy Dispersive Analysis by X-rays (EDAX) technique. The correlation between the as-taken composition and film composition will be obtained.

d) Optical Studies:

The optical absorption of $CuInTe_2$ thin films will be obtained by using UV-Vis (Ultraviolet-Visible) spectrophotometer. The coefficient of absorption, band gap energy (Eg), and nature of transition will be obtained from optical absorption spectra.

e) Electrical and thermoelectrical Studies:

The dc electrical conductivity measurements of as-deposited $CuInTe_2$ thin films will be carried out. The room temperature conductivity and activation energy will be obtained and correlated with film properties.

f) PEC studies:

To study the application of $CuInTe_2$ thin films, the deposited films on amorphous and FTO-coated conducting glass substrates will be used as active photoelectrode in photoelectrochemical (PEC) solar cells. The PEC solar cell parameters like the Junction Identity factor in the dark and under illumination, short circuit current (I_{sc}), open circuit voltage (V_{oc}), fill factor, efficiency, series and shunt resistances will be obtained. The PEC cell will be studied for capacitance-voltage (C-V) characteristics, power output characteristics and spectral response characteristics.

g) Study the effect of film thickness:

The thickness of the optimized electrode of $CuInTe_2$ thin films will be increased and will be studied for the all above characteristics.

5. Importance of the study:

Solar energy is an alternative to conventional non-renewable energy sources. To meet the increasing demands of electricity in the modern era and to reduce environmental pollution caused by some conventional energy sources, it is the need of the hour to develop efficient ways to harness solar energy. Compared with conventional silicon-based solar cells, thin film solar cells have the potential to be more cost-effective, lightweight, flexible and with the potential to have better performance. The I-III-VI_2 ternary chalcogenide semiconductors have recently attracted increased attention due to their potential applications in domains like solar cells and optoelectronic devices. Among these ternary chalcogenide materials, $CuInTe_2$ has a direct band gap in the required range for solar energy conversion and a high absorption coefficient. Hence, it is a capable material for the fabrication of solar cells and photovoltaic devices. Hence, good-quality $CuInTe_2$ thin films will

be formed, and their properties and suitability for application in solar cells will be studied in this research work.

6. Proposed work plan/ formulation and structure of study:

Work plan and target to be achieved year-wise:

a) Plan of work and targets to be achieved during the First Year:

A detailed literature survey will be done in order to get more and deep information about work already done and determine the scope of the present work. Required chemicals will be acquired. Efforts will be made to deposit good-quality $CuInTe_2$ thin films. Two progress reports will be submitted at the end of this year.

b) Plan of work and targets to be achieved during the Second Year:

In the second year, all deposition parameters will be optimized in order to deposit good-quality $CuInTe_2$ thin films. All the deposited films will be characterized by different characterization techniques such as XRD, SEM, EDAX, and UV-Vis Spectroscopy, and the structural, morphological, compositional, optical and electrical properties will be studied. Efforts will be made to submit two or more research papers to reputed international research journals. Two progress reports will be submitted at the end of this year.

c) Plan of work and targets to be achieved during the Third Year:

The results of research in the second year will be further analyzed and published in reputed journals. We will strive to present the research findings in National and International Seminars, Workshops, and Conferences during the third year. The final synopsis will be submitted and after that, the thesis will be written. The completed thesis will be submitted to the university.

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